University of Leicester

X-ray & Observational Astronomy

Chandra observations of five ULXs in nearby galaxies

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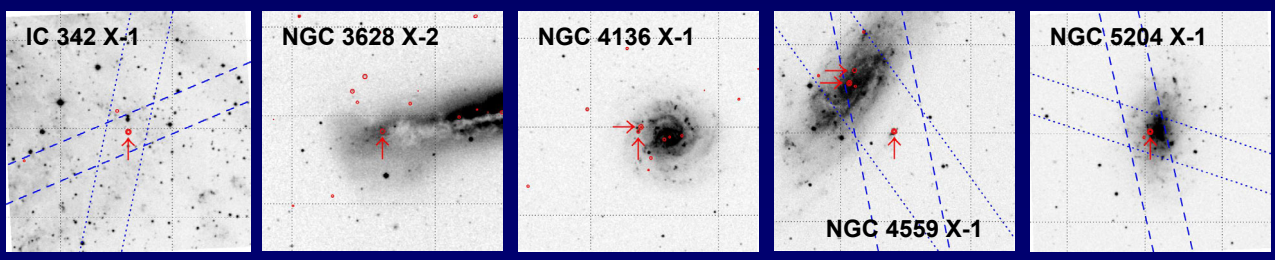

FIGURE 1: ULX locations. Each panel is equivalent to an 8.1 × 8.1 arcmin² ACIS-S3 field-of-view, centred on the target ULX (highlighted with a vertical arrow), with the X-ray emission contours overlaid in red. Three field ULX are shown by horizontal arrows. Subarrays used in the first and second epoch observations are highlighted by dashed and dotted lines respectively.

CHANDRA RESULTS

• Five ULXs were observed twice by *Chandra* over 3 – 5 month intervals.

• All five target ULXs are detected (though two have now faded below 10^{39} erg s^{-1}), and three additional field ULXs found (two previously unknown).

• All ULXs point-like, variable over long timescales → single X-ray source. Majority are persistent, L_X varying by factors ≤ 4 – similar to HMXBs?

• Short-term variability only seen in two sources, in one of two epochs per source. Argues against relativistic beaming as the dominant mechanism.

• Spectra analysed for six ULXs in two epochs each. Four best fit by powerlaw continua, one by multi-colour disc blackbody, other ambiguous. Two of the powerlaw fits require the addition of a very soft component in at least one epoch for statistical acceptability.

• Three sources show a degree of spectral hardening between their lower and higher observed X-ray fluxes, the other three soften.

• Observed states and state changes reminiscent of the complex behaviour of Galactic black hole X-ray binaries. Accretion onto intermediate-mass black holes cannot be excluded, but note that small super-Eddington ratios (L_X/L_{Edd} < 5) – seen in some outbursting SXTs – would allow these ULXs to contain 10 – 20 solar mass black holes.

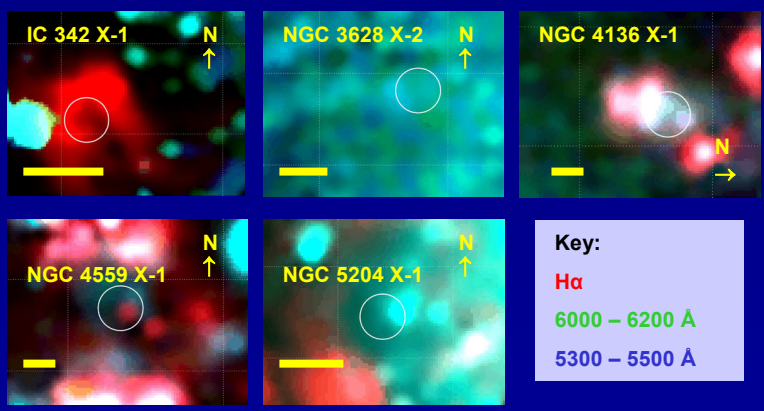

FIGURE 3: 3-colour images of the ULX environments. Each image is 16.55 × 12.25 arcsec² in size. Circles mark the uncertainty in the ULX position. We show two continuum bands (see Key) and continuum-subtracted Hα emission. The yellow scale bar represents 100 pc at the distance of the host galaxy.

The strange case of NGC 4559 X-1

• January 2001 spectrum dominated by Γ ~ 1.7 powerlaw continuum, with a hint of soft excess (kT_{in} ~ 0.2 keV MCD BB).

• June 2001 spectrum shows steeper powerlaw (Γ ~ 2.3) plus a cool MEKAL thermal plasma (kT ~ 0.2 keV). The plasma luminosity is ~ 3 × 10^{39} erg s^{-1}.

• Plasma emission measure implies gas extends > 10^9 km – not in accretion disc.

• Plasma much softer than emission-line spectra of some high-mass X-ray binaries (e.g. Cyg X-3) → not a stellar wind photoionized by the hard X-ray continuum.

• Origin in a shell of matter ejected from an evolved secondary star, shock-heated by the impact of jets from the ULX?

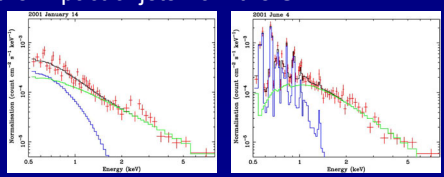

FIGURE 2: Unfolded spectra of NGC 4559 X-1

INTEGRAL IFU RESULTS

• The environments of all five ULXs were observed by the WHT/INTEGRAL integral field unit (IFU) as part of a larger survey.

• These ULXs demonstrate the range of phenomena seen in ULX environments.

• The general locations of the ULXs are consistent with star forming regions of their host galaxies (see Fig 1); we find possible star forming signatures in 10/14 INTEGRAL ULX fields. This argues that even in "normal" galaxies the majority of the ULXs are associated with young stellar populations.

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